Copy No.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA Program Apollo Working Paper No. 1319

MASK BREATHING SYSTEM FOR THE APOLLO COMMAND MODULE

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

June 30, 1967

NASA PROGRAM APOLLO WORKING PAPER NO. 1339

MASK BREATHING SYSTEM FOR THE APOLLO COMMAND MODULE

PREPARED BY

Donald F. Price
Environmental Control Systems Branch

Roger N. Tanner
Environmental Control Systems Branch

AUTHORIZED FOR DISTRIBUTION

for Maxime A. Faget
Director of Engineering and Development

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
June 30, 1967

CONTENTS

FIGURES

MASK BREATHING SYSTEM FOR THE

APOLLO COMMAND MODULE

By Donald F. Price and Roger N. Tanner

1.0 GUIDELINES

An auxiliary Mask Breathing System can provide shirtsleeve crewmen sufficient breathing time to don suits and connect to the suit circuit in the event of cabin atmosphere contamination. The primary ground rules in the conceptual design of such a system are as follows:

1. A cabin fire will be extinguished quickly leaving smoke and fumes in the cabin.

2. The Environmental Control Unit (ECU) operation will not be impaired by the fire (or other atmospheric contamination problem).

3. Emergency procedures will eliminate suit circuit in-leakage with a controlled purge which will pressurize the suit circuit above cabin during emergency operation and suit donning.

4. The Mask Breathing System must be readily accessible at all times with a minimum of crew operations, for activation.

5. Spacecraft systems modifications required for inclusion of the Mask Breathing System must be minimal.

6. The Mask Breathing System will provide protection from eye irritation.

7. Mask operation time should not be critical to the design.

2.0 SYSTEM DESCRIPTION

The proposed Mask Breathing System consists of a Manifold Block containing a three-position Mode Selector Valve, an Oxygen Purge Valve, a suit hose connector to mate with the existing suit hoses, an auxiliary connector to mate with the suit hose connector on the spacecraft, two disconnects to mate with the mask hoses, and a quick disconnect for connection of a Purge Utility Line Assembly.

The oxygen mask is a fullface type, covering the eyes and oral-nasal area, with a second set of suit hoses, or a new set of hoses of sufficient length to provide crewman mobility, attached. The mask must have quick don and doff features. Each crewman would have a Manifold Block and mask (see fig. 1).

The Purge Utility Line Assembly provides connection between the Portable Life Support System (PLSS) fill port and manifold block during emergency suit purge operations. An orifice, to limit flow to 0.42 lb O_2/min, a relief valve to prevent overpressurization, and quick disconnect ends are incorporated in the line. Only one Purge Utility Line Assembly is provided to be used by the astronauts sequentially.

3.0 GENERAL OPERATIONAL DESCRIPTION

During normal shirtsleeve or suited operation, the suit hoses, breathing mask, and mask hoses would be connected to the Manifold Block with the Mode Selector Valve in a position which would allow spacecraft operation as presently planned. During suited operation the mask and mask hoses could be disconnected if desired.

In the event of a fire, the cabin pressure will probably rise to 6.2 psia, the relief setting on the cabin pressure relief valve. To prevent contamination of the suit loop during this pressure rise and subsequent operations with a contaminated cabin: (1) the Manual Oxygen Valve must be opened to allow purge and metabolic oxygen flow directly to the suit circuit; (2) the suit return air check valve should be closed to prevent cabin air from entering the suit circuit; (3) the cabin depressurization shutoff valve should be closed to disable the cabin pressure and suit demand regulators; and (4) the Mode Selector Valve on the Manifold Block must be placed in a position to establish suit circuit integrity, unless the mask is immediately donned. In this instance, the mode selector must be placed in a position to allow mask breathing. The crewmen have the option of breathing from the mask immediately or waiting until a short suit circuit purge has been achieved, during emergency operations.

Oxygen flow to the breathing mask is limited to 4 actual cfm by a restrictor in the Manifold Block. The remainder of the flow from the ECU is bypassed through the normal suit bypass valve in the suit circuit. Due to the positive pressure in the suit circuit during emergency operations, crewmen utilizing the breathing mask will have to "pressure breathe." The pressure in the mask will range from 5 to 12 inches of water above cabin, depending on the suit demand pressure regulator relief mode operation and the purge flow rate.

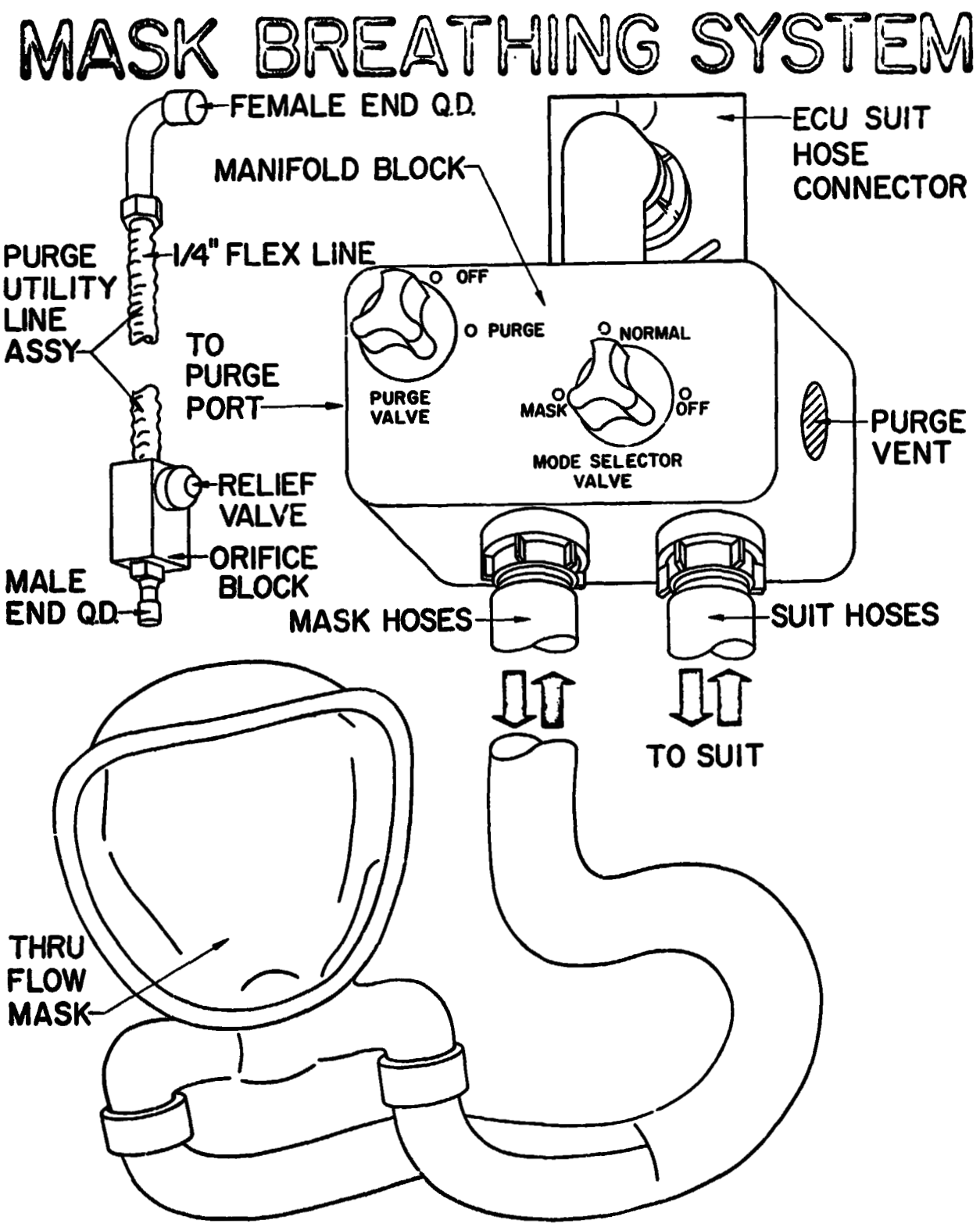

Figure 1.- Mask Breathing System

The Manual Oxygen Valve is a new component which is presently planned for installation in the spacecraft, without respect to the mask installation, for suit circuit purge. The demand pressure regulator's normal function of maintaining the suit circuit 3 inches of water less than cabin at the compressor inlet is ceased during suit circuit purge. Only the relief portion of the regulator which will maintain the suit circuit a maximum of 9 inches of water above cabin at the compressor inlet would be utilized, thus preventing possible in-leakage. The Manual Oxygen Valve should provide a high flow rate (within the capabilities of the oxygen supply system) sufficient to purge the suit circuit quickly before the mask is donned. Normal flow rate requirements are metabolic oxygen consumption plus leakages.

4.0 SYSTEMS INTEGRATION CONSIDERATIONS

Emergency suit donning and purge capability is provided by the Manifold Block while maintaining the suit circuit at a positive pressure with respect to cabin. Suit and helmet purge flow is obtained via the Purge Utility Line Assembly from the spacecraft surge tanks. Each surge tank will provide at least 8 minutes of purge flow at a maximum rate of 0.42 lb O_2/min. The second surge tank should be accessible if required for contingencies.

After the crewmen have suited and reconnected to the suit circuit, the spacecraft cabin could be cleared of contamination by depressurization if desired.

During emergency operations with the Manual Oxygen Valve open, oxygen is flowing directly into the suit loop from the spacecraft surge tanks. This could affect surge-tank pressure which determines available suit-purge time during suit donning (provided that the installed valve could flow more oxygen than could be resupplied from the spacecraft cryogenics). Therefore, after the initial pressurization and purge of suit circuit, the flow to the suit circuit must be metered by the Manual Oxygen Valve, such that the surge-tank pressure is not affected. About 2.5 to 9.0 lb O_2/hr are available from the cryogenic system without affecting surge-tank pressure, depending on the time requirement. Extended withdrawal times at rates in excess of 2.5 lb O_2/hr will affect the cryogenic tank pressure and surge-tank pressure.

The proposed concept requires no spacecraft modifications. However, a variable suit purge flow will result if the proposed orifice in the Purge Utility Line Assembly is used (rather than a pressure regulator) during surge-tank pressure decay with high oxygen withdrawal. This application should be acceptable since the initial high flow will affect the toxic gas sweep-out in the suit with the subsequently lower flow

providing a continuous positive pressure purge for final suit buttoning-up. Should the flow variation prove undesirable, a regulator could be substituted for the orifice; or a new line, shutoff valve, and disconnect could be installed downstream of the existing 4.24, 100 psia regulator for attachment of the Purge Utility Line Assembly.

5.0 SPACECRAFT OPERATIONAL MODE

The following situations illustrate the various modes of spacecraft operation, both normal and emergency. Only those valves and controls which relate to the ECU and Mask Breathing System are considered. The transition from mode to mode will be procedurally explained in the following section.

1. Normal Shirtsleeve Operation, figure 2.

a. The Cabin Depressurization Shutoff Valve (4.28) is open, allowing O_2 flow to the cabin pressure regulator and suit demand regulator.

b. The Manual Oxygen Valve (X.XX) is closed, preventing direct O_2 flow into the suit circuit.

c. The Suit Circuit is 3 inches of water less than cabin pressure at the compressor inlet, controlled by the demand regulator.

d. The Manifold Block assembly is connected to the suit circuit hoses and spacecraft suit hose connector with the Mode Selector Valve in the "Normal" position allowing suit circuit flow to the cabin.

e. The Suit Circuit Return Air Check Valve (1.3) is open, allowing cabin air to be drawn into suit circuit for CO_2 removal and cooling.

f. The breathing mask and mask hoses are connected to the Manifold Block, with no flow through the mask.

2. Suit Loop Operation, figure 3.

a. The Suit Circuit Return Air Check Valve (1.3) is closed, preventing cabin air from entering the suit circuit.

b. The Cabin Depressurization Shutoff Valve (4.28) is open, allowing O_2 flow to the cabin pressure regulator and suit demand regulator.

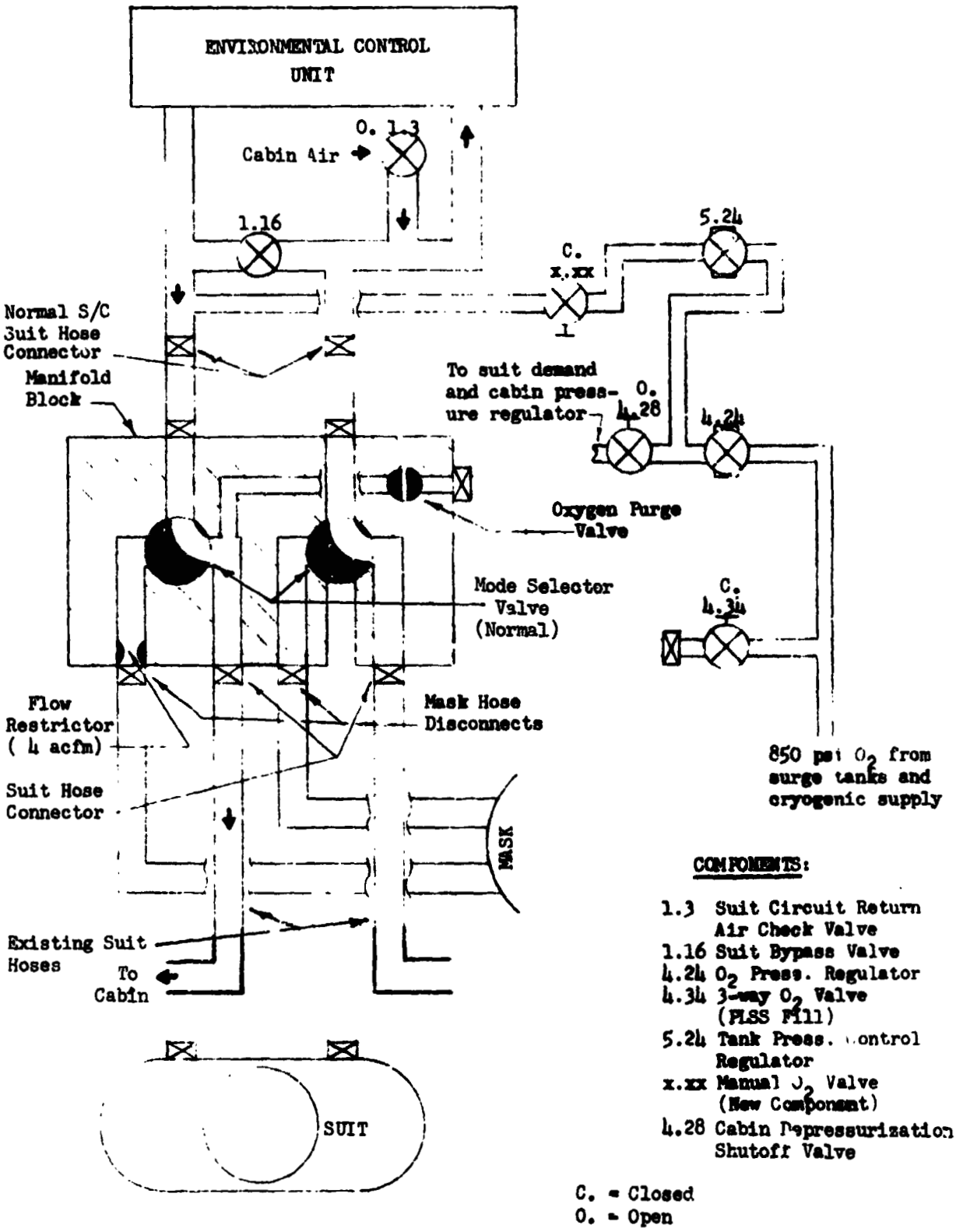

Figure 2.- Normal shirtsleeves operation.

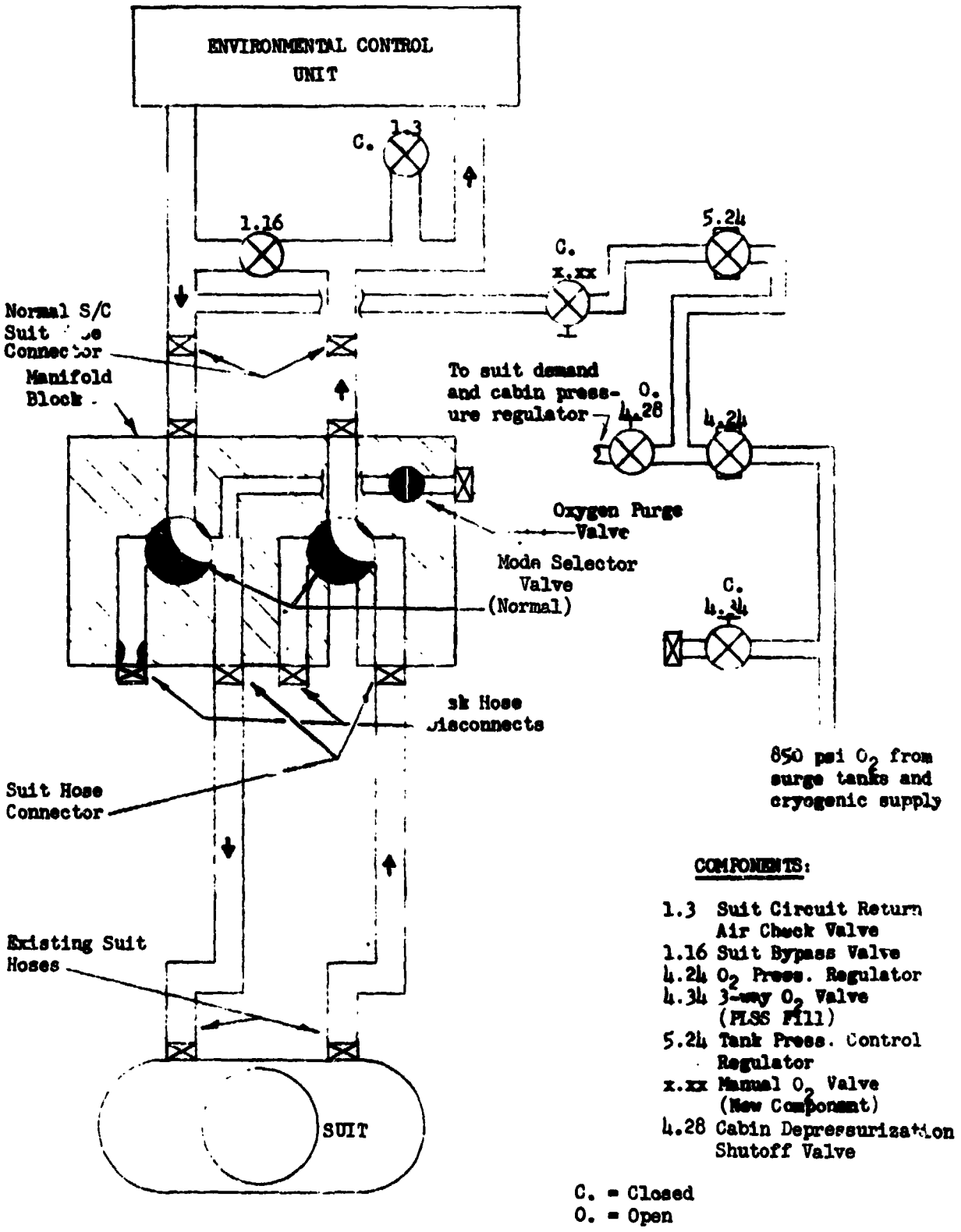

Figure 3.- Suit loop operation.

c. The Manual Oxygen Valve (X.XX) is closed.

d. The Suit Circuit is 1 to 3 inches of water below cabin pressure at the compressor inlet (Suits slightly positive).

e. The Manifold Selector Valve is in the "Normal" position, allowing ECU flow to and from the suit.

f. The mask and mask hoses are valved off and/or disconnected.

3. Emergency Mask Operation (Cabin Atmosphere Contaminated), figure 4.

a. The Suit Circuit Return Air Check Valve (1.3) is closed, preventing cabin air from entering the suit circuit.

b. The Cabin Depressurization Shutoff Valve (4.28) is closed, stopping O_2 flow to the cabin pressure regulator and suit demand regulator.

c. The Manual Oxygen Valve (X.XX) is open to meter oxygen to the suit circuit to maintain positive pressure.

d. The Suit Circuit is 9 inches of water, maximum, above cabin pressure at the compressor inlet, controlled by the demand regulator relief function.

e. The Mode Selector Valve is in the "Mask" position, providing 4 cfm to the mask and shutting off flow to the cabin.

6.0 EMERGENCY MASK BREATHING SYSTEM UTILIZATION SEQUENCE

The proposed mask system will allow a crewman, with assistance as required, to don the suit and connect to a purged suit circuit while it is maintained 9 inches of water, maximum, above cabin pressure. This is required to prevent contaminated cabin air from entering the suit circuit. The general emergency and suit donning procedures from normal shirtsleeve operation (fig. 2) are as follows:

1. a. Upon atmospheric contamination, initiate suit circuit purge by opening the Manual Oxygen Valve (X.XX).

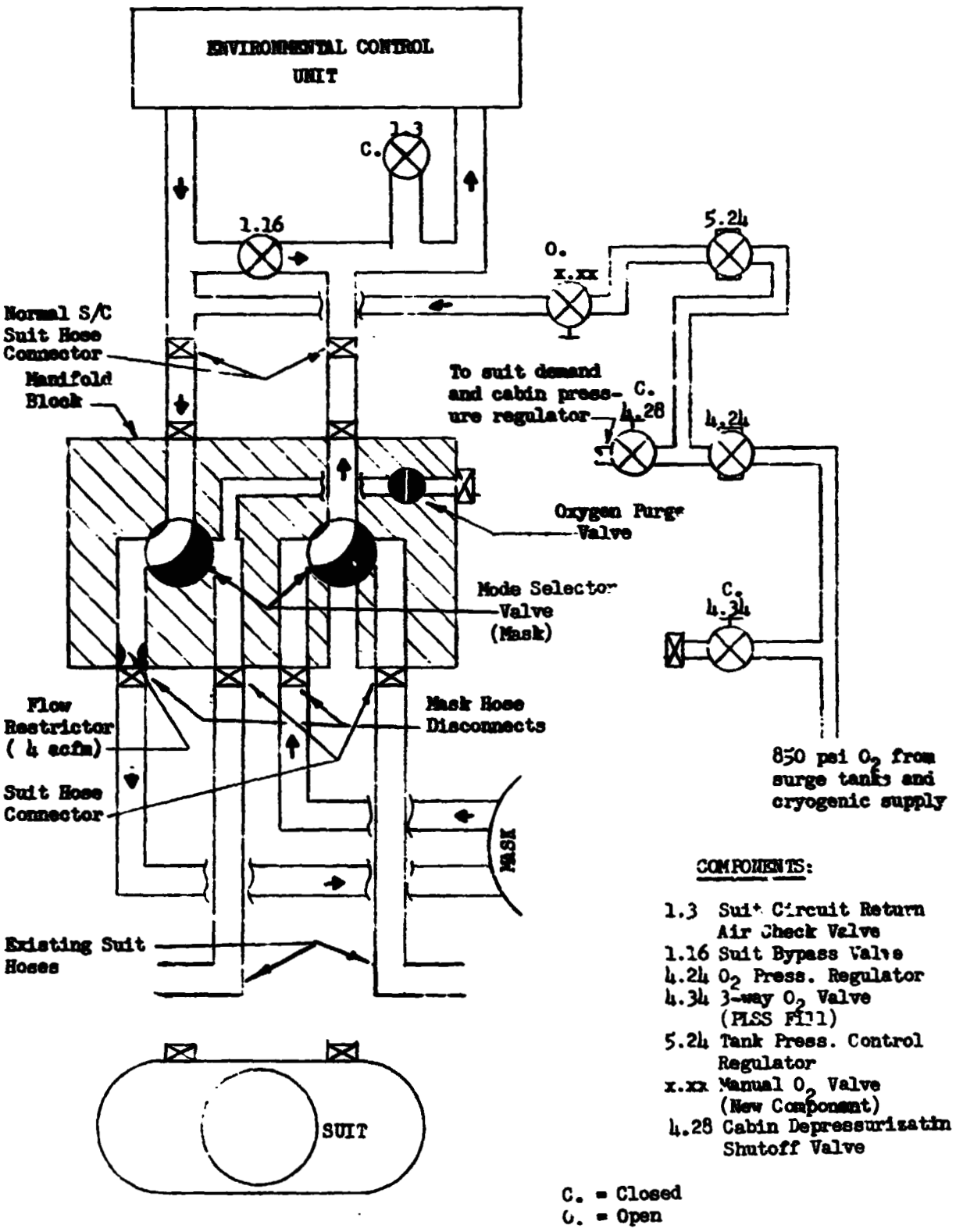

Figure 4.- Emergency mask operation.

b. Place the Manifold Block, Mode Selector Valve to the "Off" position to isolate the ECU.[1]

c. Manually shut off the Suit Circuit Return Air Check Valve (1.3) and the Cabin Depressurization Shutoff Valve (4.28). (See fig. 5.)

2. When ready to don mask, place the Manifold Block, Mode Selector Valve to the "Mask" position and affix mask. (See fig. 4.)

3. When ready to don suits connect the Purge Utility Line Assembly between the Manifold Block and the Three-Way Oxygen Valve Assembly (4.34) (PLSS Fill Valve). (See fig. 6.)

4. a. Don suit except gloves and helmet.[2]

b. Connect suit inlet and outlet hoses from the manifold block to the suit hose inlet and outlet hose connectors on the suit.

5. Open the Oxygen Purge Valve on the Manifold Block and slowly open the Three-Way Oxygen Valve (4.34) to start suit purge flow. (See fig. 6.) Purge suit 1 to 2 minutes with suit diverter valves in the horizontal position (flow split between suit torso and helmet duct).

6. Install purge fitting in the Emergency Oxygen Supply (EOS) connection on helmet.

7. Don suit gloves.

8. a. Hold breath; place Manifold Block Mode Selector Valve to the "Off" position; remove mask and lock helmet in place.

b. The crewman may begin breathing after a few seconds of helmet purge. (Note: The suit flow diverter valve should be left in the horizontal position to maintain flow from suit and out helmet purge valve so as to not contaminate the suit while purging the helmet.) (See fig. 7.)

9. a. Remove purge fitting from helmet; place Manifold Block Selector Valve to "Normal" and stop purge flow by closing the Three-Way Oxygen Valve (4.34).

---

[1]If desired, the mask may be affixed immediately, in which case the Manifold Block, Mode Selector Valve should be placed to the "Mask" position.

[2]In the suit donning procedure, the mask must be momentarily removed to allow the head to pass through the neck ring. The mask should be isolated from the LCU during this operation.

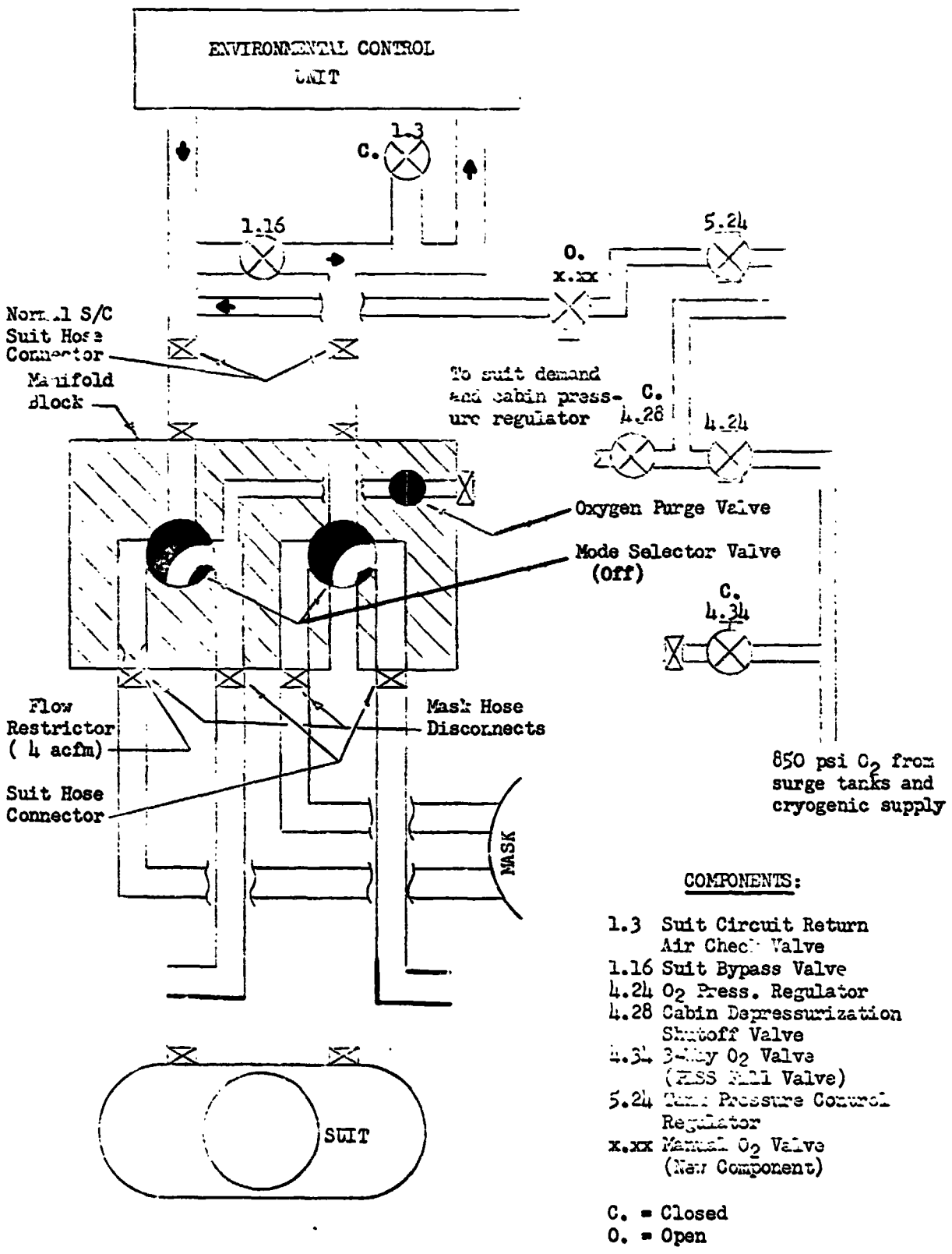

Figure 5.- Suit loop purge.

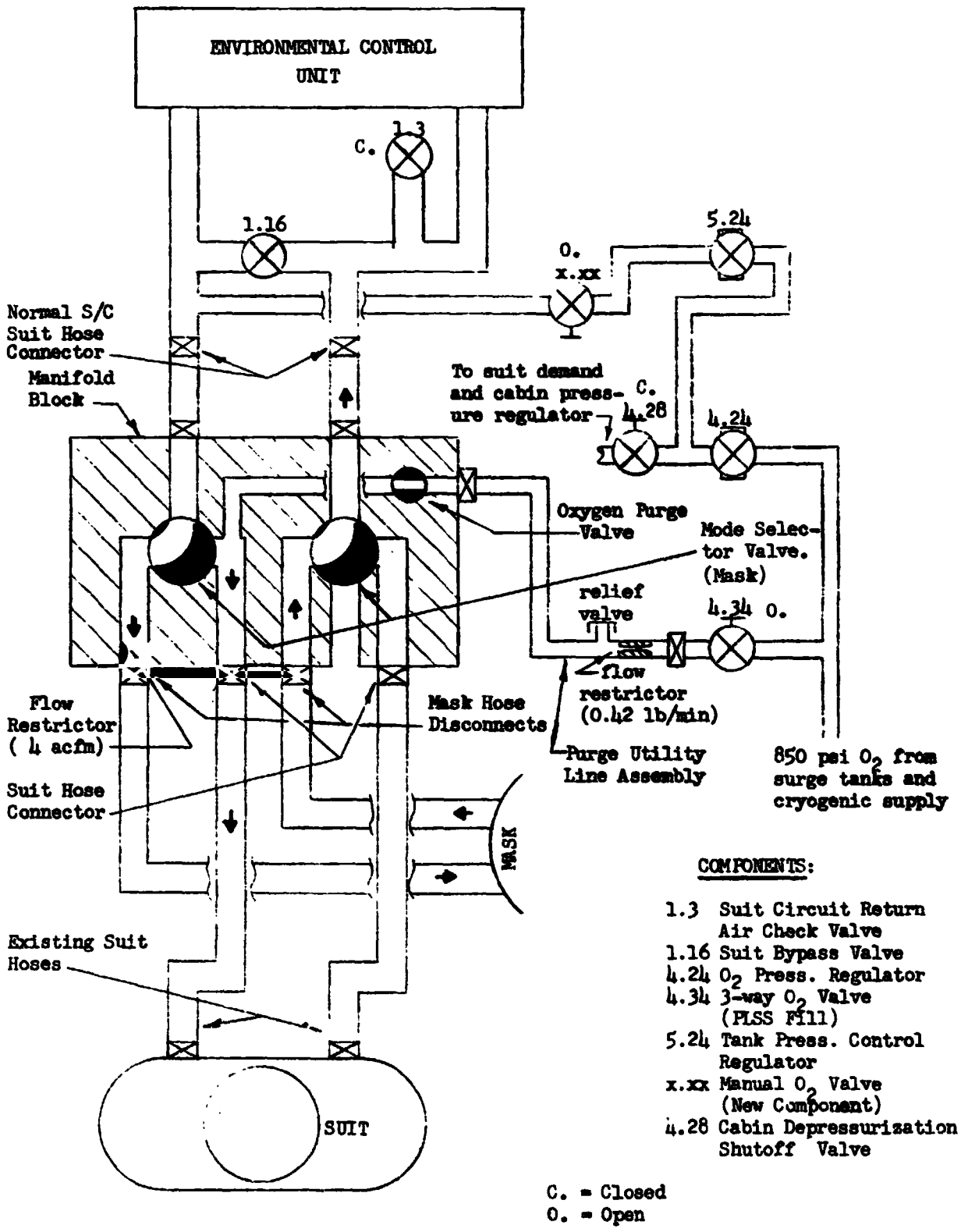

Figure 6.- Shirtsleeves operation with mask while purging suit.

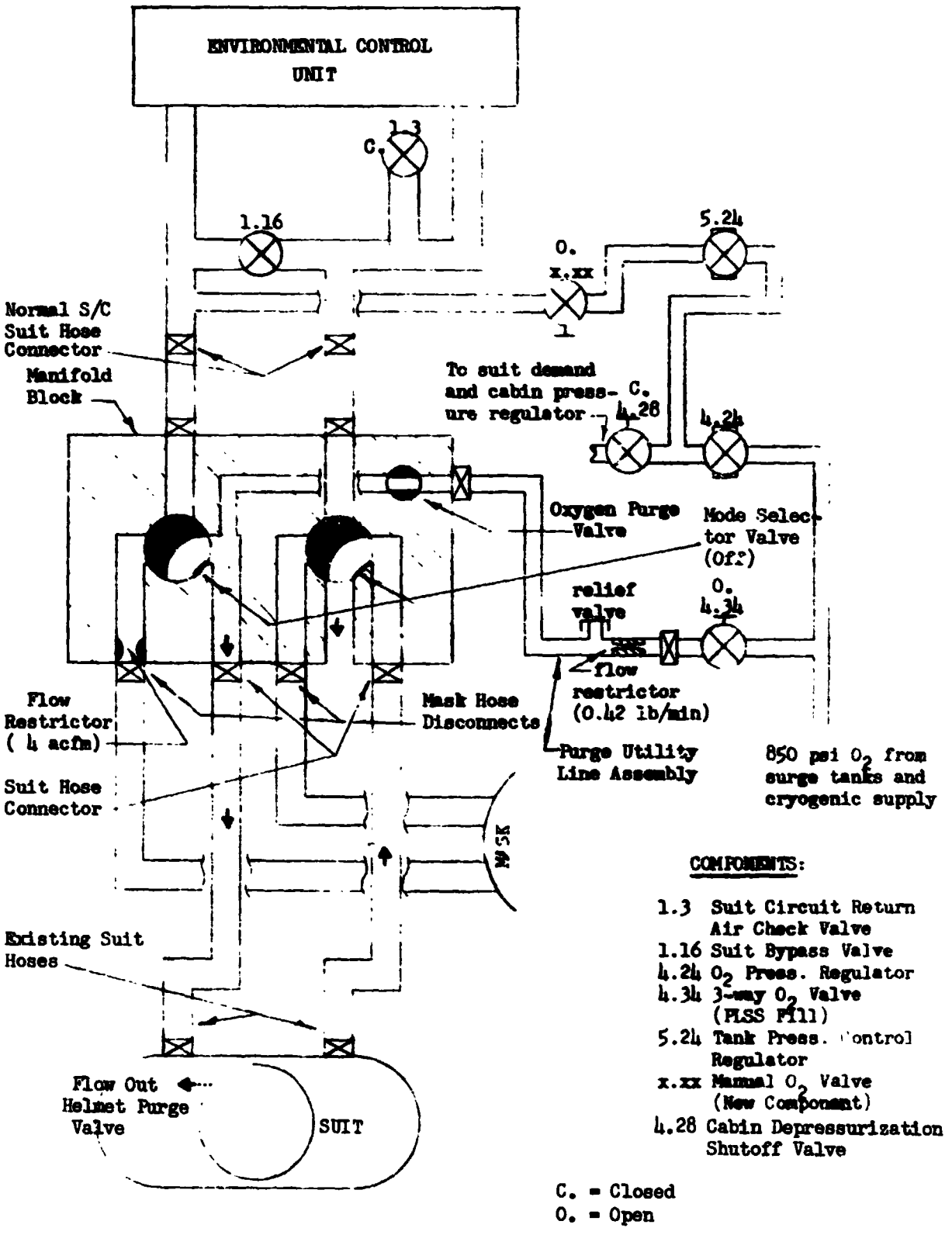

Figure 7.- Final suit and helmet purge with mask removed.

b. Turn oxygen purge valve to "Off" (on the Manifold Block) and disconnect the Purge Utility Line Assembly from the Three-Way Oxygen Valve (4.34) (PLSS Fill Valve) and Manifold Block.[3]

c. Mask and mask hoses may be disconnected, if desired (fig. 3).

10. The next crewman may begin the above procedure after the surge tank has recharged sufficiently.

7.0 DEMONSTRATION TESTS

The following tests were performed to evaluate the feasibility of the proposed mask breathing system.

1. Mask Flow Test — A test was conducted to determine the flow required through a double-hose face mask to provide breathing and carbon dioxide level control, with a steady-state mask inlet pressure of 12 inches of water. (This would be the maximum condition when breathing from the spacecraft ECU.) With a test subject working at a metabolic rate of about 2000 Btu/hr, the mask pressure during inhalation was 2 to 3 inches of water positive with 4 cfm, indicating sufficient flow was being provided for breathing. During exhalation, the mask pressure was 13 to 14 inches of water positive which simulated spacecraft operation. It was shown that flows as low as 3 cfm controlled the carbon dioxide level in the mask to less than 1 percent; however, there was not sufficient flow available for breathing. (The mask pressure during inhalation was -6 inches of water.)

2. Helmet Donning Tests — An Apollo A-5-L suit was tested under various configurations and flows to determine if the helmet could be donned with flow to the suit. The following tests were conducted with the suit outlet vented to ambient and inlet flow provided by a suit checkout console:

a. Flow of 12 scfm air to entire Pressure Garment Assembly (PGA) with an EOS probe inserted in the helmet. Donning time <15 seconds.

b. Flow of 12 scfm air to helmet only with an EOS probe inserted in helmet. Donning time <15 seconds.

---

[3]During suit purge operations, the crewman should monitor surge-tank pressure. The tanks may have to be allowed time to refill between suit donnings.

c. Flow of 12 scfm air to helmet only with no EOS probe in helmet. Donning time <15 seconds.

d. Flow of 12 scfm air to entire PGA with no EOS probe in helmet. Donning time <15 seconds.

e. Flow of 16.5 scfm air to helmet only with no EOS probe in helmet. Donning time <10 seconds. Suit pressure was 0.75 psig (20 inches of water).

8.0 COMMENTS

At 6.2 psia, 12 cfm is equal to 0.42 lb/min oxygen which is the recommended suit purge rate for the proposed Mask Breathing System. The duration of the donning time was a function of the ease of locking the helmet in place. The flow rate and resultant suit pressure did not alter the performance of the subject in donning the helmet as much as the actual locking of the helmet neck ring. For these tests an EOS probe was used instead of a purge valve due to the unavailability of a purge valve fitting at this time. However, the opening through the purge valve will be about the same size as the EOS probe; therefore, the test results were not significantly affected.